Aluminium – Copper – Erbium

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Literature Data

A critical review of the literature data up to 1989 has been made by [1991Ran] and later literature considered in a general review of the crystallochemical and phase equilibria of the R-Cu-Al systems (R = rare-earth) by [2003Ria]. Different compounds have been identified and their crystal structures determined: (1) ErCuAl by [1968Dwi, 1973Oes, 1989Kuz], with a high pressure modification reported by [1987Tsv1, 1987Tsv2], (2) ErCuAl3 by [1988Kuz, 1989Kuz], (3) ErCu4Al by [1978Tak], (4) Er2Cu7Al10 by [1982Pre, 1989Kuz], (5) ErCu4Al9 by [1976Bus, 1979Fel, 1989Kuz], (6) ErCu4Al6 by [1980Fel, 1981Fel] and (7) ErCu0.9Al2.1 reported by [1992Kuz].

The alloys generally were prepared from 99.5% to 99.9 mass% Er and higher purity Cu and Al. They were melted either by arc melting or under argon protection in induction furnaces using MgO crucibles; followed by homogenization heat treatments. [1989Kuz] studied the phase equilibria at 600°C by X-ray powder analysis on 107 samples and reported trends in the lattice parameters for a number of solid solutions. [1974Oes] studied the homogeneity ranges of Er(Cu1-xAlx)2 and Er(CuAl1-xAlx)2 and determined the limits of solubility by the appearance of X-ray diffraction lines characterizing a new phase. The results reveal that copper in ErCu2 can be replaced by up to about 1.5 mole% aluminium and that in ErAl2 up to about 15 mole% aluminium can be replaced by copper.

Binary Systems

The reported ternary experimental data are limited and can be summarized in the isothermal section at 600°C, which is consistent in its binary boundaries with (a) the Al-Er phase diagram by [1988Gsc], the Al-Cu phase diagram by [2003Gro] and Er-Cu as reported by [1994Sub]. Amendments have been made to the reported crystal structure data based on [2003Ria].

Solid Phases

According to [1980Fel] the ThMn12 type structure is observed for RCu4Al8 and RCu6Al10, where R = rare earth from Gd to Lu and Y. From the literature it is not always explicit whether the two compositions 1:4:8 and 1:6:6 correspond to two different phases or whether they are the limits of a solid solution range. [1989Kuz] found τ1,ErCu4Al8 to be stoichiometric and did not confirm the existence of τ1,ErCu6Al10. However, on the basis of [1980Fel], we considered the τ1,Er(CuAl1−xAlx)12 as non stoichiometric with 0.33 ≤ x ≤ 0.5. Obviously its range changes with the temperature, as [1980Fel] and [1989Kuz] observed it at different compositions at different temperatures, see Table 1. The existence of a homogeneity range for the compounds R(CuAl1−xAlx)12, where R is a rare earth, was recently suspected by the same team for R = Y [2003Kra] and confirmed for R = Sc [2003Kan].

The crystal structure of the R Cu4Al phases (R = La to Sm and Gd to Tm) has been studied by [1978Tak]; this composition is included by [1989Kuz] in the homogeneity range of the phase τ3,Er(CuAl1−xAlx)5 with 0.46 ≤ x ≤ 0.82. Subsequently [1992Kuz] determined the crystal structure of the τ4,ErCu0.9Al2.1 phase as pertaining to the PuNi3 type (hR36).

Crystalllographic data for all solid phases are given in Table 1.

Isothermal Sections

Figure 1, an isothermal section at 600°C is based on the work of [1989Kuz], corrected at the Al-Cu boundary to be in agreement with the accepted binary diagram. At the Cu-Er edge of the ternary isothermal section, however, the two compounds Er2Cu7 and Er2Cu9 are omitted, although they are reported in the accepted binary, as they were not observed at this temperature in the ternary alloys by [1989Kuz]. These
two compounds, designated Er₃Cu₇ and Er₂Cu₉ by [1994Sub] have been designated as ErCuₓ and ErCuᵧ by [1970Bus], who assumes that ErCuₓ forms peritectically at 940°C, that ErCuᵧ melts congruently at 1010°C. By lack of data in the Cu-Er system these assumptions are based on the melting behavior of other similar rare earth-copper compounds.

Inside the ternary system there are four ternary solid solutions: (1) τ₄, Er(CuₓAl₁₋ₓ)₁₂ (ThMn₁₂ type), which is shown as a stoichiometric phase at this temperature according to [1989Kuz], (2) τ₂, Er₂(CuₓAl₁₋ₓ)₁₇ with Th₂Zn₁₇ type structure and a solution range of 0.41 ≤ x ≤ 0.56, (3) τ₃, Er(CuₓAl₁₋ₓ)₃ in a range of 0.46 ≤ x ≤ 0.82 and with a CaCu₃ type structure and (4) the τ₅, ErCuAl with a small solubility range and ZrNiAl type structure.

Three stoichiometric compounds have been found. (I) Er₄Cu₆Al₉ (PuNi₃ type) for which [1992Kuz] suggested that it assimilates with ErCu₀.₉Al₂.₁(τ₄) (PuNi₃ type) in samples annealed at 600°C, (II) the τ₆,ErCuAl₃ being of HoCuAl₃ type structure and (II) the τ₇,Er₂Cu₃Al₅ whose structure is unknown. At 600°C ErCu₉ dissolves up to ~1 at.% aluminium, ErCu dissolves up to ~20 at.% aluminium and ErAl₂ up to about 13 at.% copper. The τ₈,Er₆Cu₆Al₇ (Th₆Mn₂₃ type) identified by [1990Ste] has not been observed at 600°C by [1989Kuz]. Its position in the phase diagram is shown in Fig. 1, but it is not possible to draw reliable equilibrium lines between τ₈ and its surrounding phases.

Notes on Materials Properties and Applications

[1979Fel] studied the magnetism and hyperfine interactions of ¹⁵¹Eu, ¹⁵⁵Gd, ¹⁶¹Dy, ¹⁶⁶Er and ¹⁷⁰Yb in RCu₄Al₈ and [1995Cac] reported neutron spectroscopy studies of crystal-field interaction in RT₄Al₈ compounds (R = Tb, Ho, Er; T = Mn, Fe, Cu).

[1973Oes] measured the Curie temperature of the ErCuAl compound as 17 K. [1996Jav] found that ErCuAl orders ferromagnetically below Tₑₐₐₙₖ = 6.8 K with the magnetic moments parallel to the c-axis, a behavior which [1998Jav] confirmed later by measuring susceptibility, magnetization and specific heat.

[1996Mit] studied the interaction of H₂ with RCuAl (R = Dy, Ho, Er).
For the ErCu₄Al₈ compound, a type 1 antiferromagnetic structure is observed by neutron powder diffraction in [1997Bai].

References


